Heating houses

Energy flow

D–C

- **Energy**, in the form of heat, flows from a warmer to a colder body. When energy flows away from a warm object, the **temperature** of that object decreases.

Measuring temperature

D–C

- A **thermogram** uses colour to show temperature; hottest areas are white/yellow, coldest are black/dark blue/purple.

Typical range of colours used in a thermogram

B–A*

- Temperature is a measurement of hotness on an arbitrary scale. You do not need to use a thermometer. It allows one object to be compared to another.
- When the temperature of a body increases, the average **kinetic energy** of the particles increases.
- Heat is a measurement of internal energy. It is measured on an absolute scale.

Specific heat capacity

D–C

- All substances have a property called **specific heat capacity**, which is:
  – the energy needed to raise the temperature of 1 kg by 1 °C
  – measured in joule per kilogram degree Celsius (J/kg °C) and differs for different materials.
- When an object is heated and its temperature rises, energy is transferred.
- The equation for energy transfer by specific heat capacity is:

  energy transferred = mass × specific heat capacity × temperature change

Calculate the energy transferred when 30 kg of water cools from 25 °C to 5 °C.
energy transferred = 30 × 4200 × (25 – 5) = 30 × 4200 × 20
= 2 520 000 J or 2520 kJ

Specific latent heat

D–C

- **Specific latent heat** is:
  – the energy needed to melt or boil 1 kg of the material
  – measured in joule per kilogram (J/kg) and differs for different materials and each of the changes of state.
- When an object is heated and it changes state, energy is transferred, but the temperature remains constant.
- The equation for energy transfer by specific latent heat is:

  energy transferred = mass × specific latent heat

Calculate the energy transferred when 2.5 kg of water changes from solid to liquid at 0 °C
energy transferred = 2.5 × 340 000
= 850 000 J or 850 kJ


In a thermogram, white, yellow and red represent the hottest areas. Black, dark blue and purple represent the coldest areas.

B–A*

- When a substance changes state, energy is needed to break the bonds that hold the molecules together. This explains why there is no change in temperature.

Improve your grade

Specific heat capacity

Ed uses a stainless steel saucepan to heat his soup from 17 °C to 94 °C. The saucepan has a mass of 1.1 kg and a specific heat capacity of 510 J/kg °C. Energy is required to heat the soup.

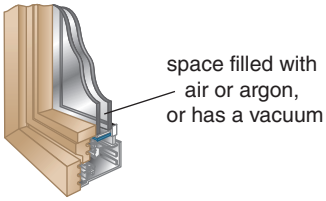
(a) Calculate the extra energy required to raise the temperature of the saucepan.
AO2 [2 marks]

(b) Ed reads that a 1.1 kg copper saucepan will be more energy efficient. Explain why.
AO2 [2 marks]

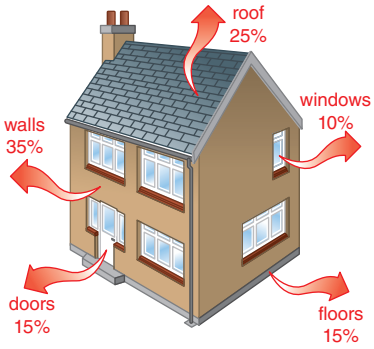
Keeping homes warm

Practical insulation

- Double glazing reduces energy loss by conduction. The gap between the two pieces of glass is filled with a gas or contains a vacuum.
  - Particles in a gas are far apart. It is very difficult to transfer energy. There are no particles in a vacuum so it is impossible to transfer energy by conduction.
- Loft **insulation** reduces energy loss by conduction and convection:
  - warm air in the home rises
  - energy is transferred through the ceiling by conduction
  - air in the loft is warmed by the top of the ceiling and is trapped in the loft insulation
  - both sides of the ceiling are at the same temperature so no energy is transferred
  - without loft insulation, the warm air in the loft can move by convection and heat the roof tiles
  - energy is transferred to the outside by conduction.
- Cavity wall insulation reduces energy loss by conduction and convection:
  - the air in the foam is a good **insulator**
  - the air cannot move by convection because it is trapped in the foam.
- Insulation blocks used to build new homes have shiny foil on both sides to reduce energy transfer by radiation:
  - energy from the Sun is reflected back to keep the home cool in summer
  - energy from the home is reflected back to keep the home warm in winter.



A double glazed window



Energy loss from a home

D–C

Remember!

Hot air will only rise into the loft if the loft-hatch is open.

Conduction, convection and radiation

- Energy can be transferred by:
  - conduction – due to the transfer of kinetic energy between particles
  - convection – a gas expands when it is heated. This makes it less dense so it rises. The unit of density is kg/m^3 or g/cm^3.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

  - **radiation** does not need a material to transfer energy. Energy can be transferred through a vacuum.

B–A*

Energy efficiency

$$\text{efficiency} = \frac{\text{useful energy output (} \times 100\ \% \text{)}}{\text{total energy input}}$$

- Energy transformations can be shown by Sankey diagrams.
- Energy from the source (home) is lost to the sink (environment).
- Different types of insulation cost different amounts and save different amounts of energy.

$$\text{payback time} = \frac{\text{cost of insulation}}{\text{annual saving}}$$

D–C

- Everything that transfers energy will waste some of the energy as heat to the surroundings.
- Buildings that are energy efficient are well insulated; little energy is lost to the surroundings.
- Designers and architects have to make sure that as little energy as possible is wasted.

Sankey diagram

B–A*

Improve your grade

Energy loss in a cavity wall

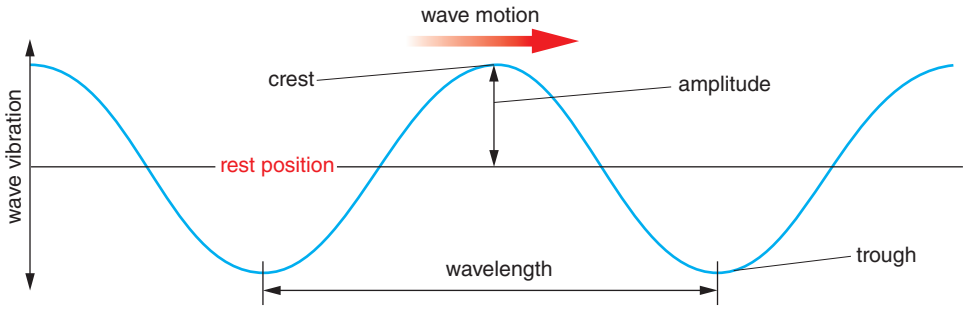
The Johnson's house has cavity walls. They decide to have foam injected into the cavity to reduce energy loss.

Explain how energy is transferred to the roof space from the cavity. *AO1* [3 marks]

A spectrum of waves

Wave properties

- The **amplitude** of a wave is the *maximum* displacement of a particle from its rest position.
- The crest of a wave is the *highest point on* a wave above its rest position.
- The trough of a wave is the *lowest point on* a wave *below* its rest position.
- The **wavelength** of a wave is the distance *between* two *successive* points on a wave having the same displacement and moving in the same direction.



A transverse wave

D–C

- The **frequency** of a wave is the number of complete waves passing a point in one second.
- The equation for the speed of a wave is:

  wave speed = frequency × wavelength

When Katie throws a stone into a pond, the distance between ripples is 0.3 m and four waves reach the edge of the pond each second.
wave speed = 0.3 × 4 = 1.2 m/s

Remember!
Always give the units in your answer:
– wavelength – metre (m)
– frequency – **hertz** (Hz)
– speed – metre per second (m/s).

B–A*

Microwaves travel at a speed of 300 x 10^6 m/s. A microwave oven uses microwaves with a frequency of 2.5 × 109 Hz. Calculate the wavelength of the microwaves.

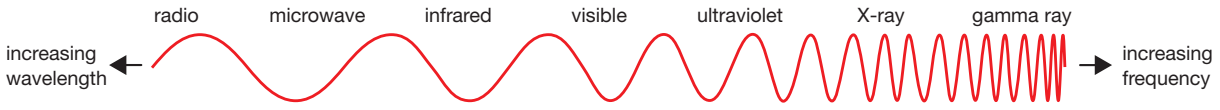
$$\text{Wavelength} = \frac{\text{wave speed}}{\text{frequency}}$$

$$= \frac{300 \times 10^6}{2.5 \times 10^9} = 0.12 \text{ m}$$

Remember!
At higher tier you may be expected to use scientific notation and rearrange equations.

Electromagnetic spectrum

D–C



Getting messages across

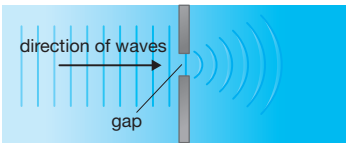
D–C

- Some optical instruments, such as the periscope, usea two or more plane mirrors.
- **Refraction** occurs because the speed of waves decreases as the wave enters a more dense medium and increases as the wave enters a less dense medium. The frequency stays the same but the wavelength changes.
- **Diffraction** is the spreading out of a wave as it passes through a gap.
- The size of a communications receiver depends on the wavelength of the radiation.

Diffraction effects

B–A*

- The amount of diffraction depends on the size of the gap; the most diffraction occurs when the gap is a similar size to the wavelength. Larger gaps show less diffraction.
- Diffraction effects are noticeable in telescopes and microscopes.



Diffraction at a narrow gap

Improve your grade

Diffraction effects

Light is diffracted as it passes through a narrow slit. Describe how the amount of diffraction depends on the wavelength of the light and the width of the slit. *AO1* [2 marks]

Light and lasers

Morse code

- The **Morse code** uses a series of dots and dashes to represent letters of the alphabet.
  - This code is used by signalling lamps as a series of short and long flashes of light.
  - It is an example of a digital signal.

D–C

Sending signals

- When a signal is sent by light, electricity, microwaves or radio, it is almost instantaneous.
- Each method of transmission has advantages and disadvantages:
  - can the signal be seen by others?
  - can wires be cut?
  - how far does the signal have to travel?

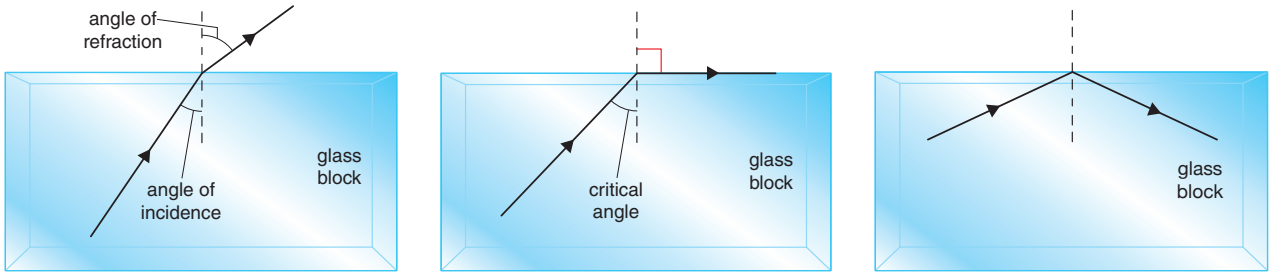
B–A*

Laser light

- White light is made up of different colours of different frequencies out of **phase**.
- **Laser** light has only a single frequency, is in phase and shows low divergence.
- Laser light is used to read from the surface of a compact disc **(CD)**:
  - the surface of the CD is pitted
  - the pits represent the digital signal
  - laser light is shone onto the CD surface and the difference in the reflection provides the information for the digital signal.

B–A*

Critical angle



The behaviour of light in an optically dense material

- When light travels from one material to another, it is normally refracted.
- If it is passing from a more dense material into a less dense, the angle of refraction is larger than the angle of incidence.
- When the angle of refraction is 90°, the angle of incidence is called the **critical angle**.
- If the angle of incidence is bigger than the critical angle, the light is reflected:
  - this is total internal reflection.
- Telephone conversations and computer data are transmitted long distances along optical fibres at the speed of light (200 000 km/s in glass).
- Some fibres are coated to improve reflection.

D–C

Endoscopy

- An **endoscope** allows doctors to see inside a body without the need for surgery.
  - Light passes along one set of optical fibres to illuminate the inside of the body.
  - The light is reflected.
  - The reflected light passes up another set of fibres to an eyepiece or camera.

B–A*

Improve your grade

Sending signals

Adam is standing on top of a hill in line of sight and 10 km away from Becky who is on top of another hill. They can communicate either by using light, radio or electrical signals. Suggest one advantage and one disadvantage of using each type of signal. *AO1* [3 marks]

Cooking and communicating using waves

Cooking with waves

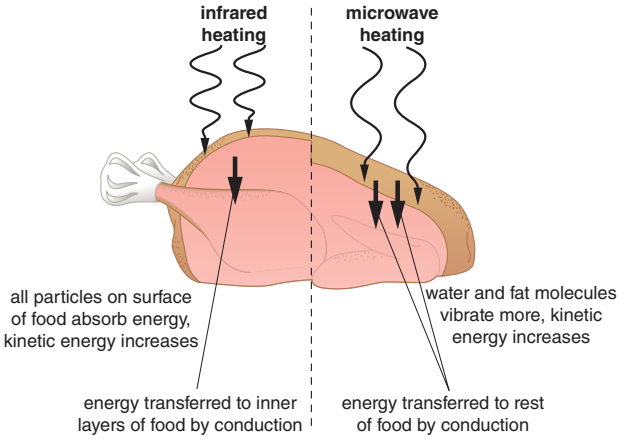
D–C

- **Infrared** radiation does not penetrate food very easily.
- **Microwaves** penetrate up to 1 cm into food.
- Microwaves can penetrate glass or plastic but are reflected by shiny metal surfaces:
  - special glass in a microwave oven door reflects microwaves
  - they can cause body tissue to burn.

Electromagnetic spectrum

B–A*

- Energy is transferred by waves:
  - the amount of energy depends on the frequency or wavelength of the wave
  - high frequency (short wavelength) waves transfer more energy.
- Normal ovens cook food by infrared radiation:
  - energy is absorbed by the surface of the food
  - the kinetic energy of the surface food particles increases
  - the rest of the food is heated by conduction.
- Microwave ovens cook food by microwave radiation:
  - the water or fat molecules in the outer layers of food vibrate more.



Cooking with infrared and microwaves

Microwave properties

B–A*

- Microwaves have wavelengths between 1 mm and 30 cm.
- Mobile phones use longer wavelengths than microwave ovens.
  - Less energy is transferred by mobile phones.

Microwave communication

D–C

- Microwave radiation is used to communicate over long distances.
- The **transmitter** and **receiver** must be in *line of sight*.
  - Aerials are normally situated on the top of high buildings.
- **Satellites** are used for microwave communication.
  - The signal from Earth is received, amplified and re-transmitted back to Earth.
  - Satellites are in line of sight because there are no obstructions in space.
  - Large aerials can handle thousands of phone calls and television channels at once.
- There are concerns about the use of mobile phones and where phone masts are situated.
- Scientists publish results of their studies to allow others to check their findings.

B–A*

- Signal strength for mobile phones can change a lot over a short distance.
  - Microwaves do not show much **diffraction**.
  - Adverse weather and large areas of water can scatter the signals.
  - The curvature of the Earth limits the line of sight so transmitters have to be on tall buildings or close together.
- Mobile phones can **interfere** with sensitive equipment:
  - They are banned on planes and in many hospitals.

Improve your grade

Microwave transmitters

The Telecom Tower in London is one of the tallest buildings in the city. There are many microwave aerials surrounding the top of the tower.

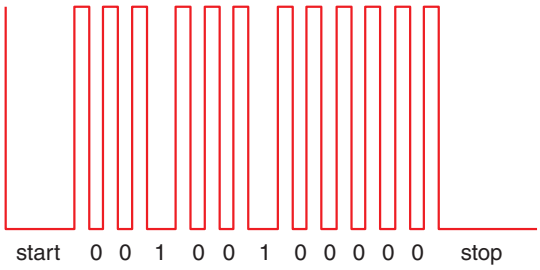
Explain why they are sited so high up. *AO1* [2 marks]

Data transmission

Digital signals

D–C

- **Infrared** signals carry information that allows electronic and electrical devices to be controlled.
- Pressing a button on the remote control device completes the circuit. A coded signal is sent to a light emitting diode or LED at the front of the remote.
- The signal includes a start command, the instruction command, a device code and a stop command.
- The LED transmits the series of pulses. This is received by the device and decoded to allow the television to change channel or volume.
- The switchover from **analogue** to **digital** started in 2009 and is planned to finish by 2015. This may be delayed until more people buy digital radios. The switchover for both radio and TV means:
  - improved signal quality for both picture and sound
  - a greater choice of programmes
  - being able to interact with the programme
  - information services such as programme guides and subtitles.



A typical digital signal from a remote

B–A*

Optical fibres

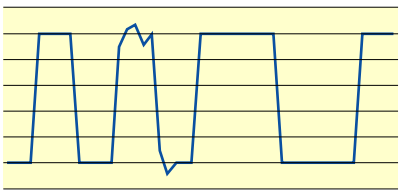
- Optical fibres allow data to be transmitted very quickly using pulses of light.

Remember!
An optical fibre is solid, not a hollow tube.

D–C

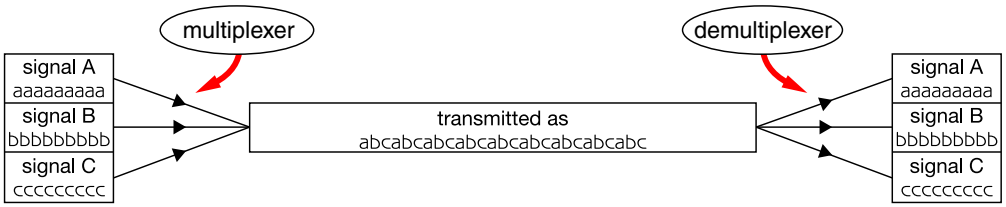
Advantages of digital signals

- Before an analogue signal is transmitted, it is added to a carrier wave.
- The **frequency** of the carrier wave is usually higher.
- The combined wave is transmitted.
- **Interference** from another wave can also be added and transmitted.
- If the wave is amplified, the interference is amplified as well.
- Interference also occurs on digital signals, but is not apparent because the digital signal only has two values.
- **Multiplexing** allows a large number of digital signals to be transmitted at the same time.



Interference on a digital wave

B–A*



Multiplexing of digital signals

Improve your grade

Advantages of using digital signals and optical fibres

Explain the advantages of using digital signals and optical fibres compared with analogue signals and electrical cables for data transmission. *AO1* [4 marks]

Wireless signals

Radio refraction and interference

- Wireless technology is used by:
  - radio and television
  - laptops
  - mobile phones.
- **Radio waves** are reflected and refracted in the Earth's atmosphere:
  - the amount of **refraction** depends on the frequency of the wave
  - there is less refraction at higher **frequencies**.
- Radio stations broadcast signals with a particular frequency.
- The same frequency can be used by more than one radio station:
  - the radio stations are too far away from each other to interfere
  - but in unusual weather conditions, the radio waves can travel further and the broadcasts interfere.
- **Interference** is reduced if **digital signals** are used.
- Digital Audio Broadcasting or DAB also provides a greater choice of radio stations but the audio quality is not as good as the FM signals currently used.
- DAB eliminates interference between other radio stations.

Radio reflection

- Radio waves are reflected from the **ionosphere**. They behave like light in an optical fibre and undergo total internal reflection.
- Water reflects radio waves but land mass does not.
- Continued reflection by the ionosphere and the oceans allows radio waves to be received from an aerial that is not in line of sight.
- **Microwaves** pass through the ionosphere.
- Microwave signals are received by orbiting **satellites**, amplified and retransmitted back to Earth.
- Communication satellites orbit above the equator and take 24 hours to orbit Earth.

Remember!
Microwave signals are not reflected from satellites.

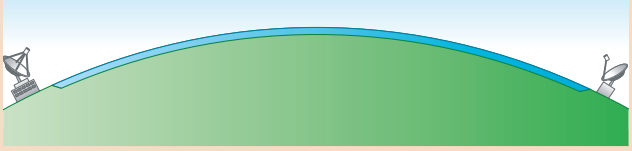
Communication problems

- Radio waves are diffracted when they meet an obstruction.
- Refraction in the atmosphere needs to be taken into account when sending a signal to a satellite.
- The transmitting aerial needs to send a focused beam to the satellite because its aerial is very small.
- The transmitted beam is slightly divergent.
- Some energy is lost from the edge of the transmitting aerial because of diffraction.

Improve your grade

Radio communication

The picture shows a transmitter and receiver on the Earth's surface, out of line of sight.



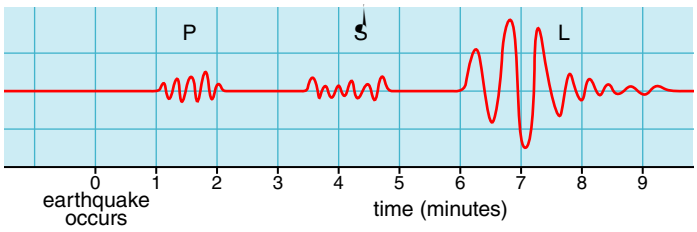
(a) Explain how long wave radio signals travel from the transmitter to the receiver. *[3 marks AO1]*

(b) Explain how microwave signals travel from the transmitter to the receiver. *AO1* [2 marks]

Stable Earth

Earthquake waves

- A seismograph shows the different types of earthquake wave.
- L waves travel round the surface very slowly.
- **P waves** are longitudinal pressure waves:
  - P waves travel through the Earth at between 5 km/s and 8 km/s
  - P waves can pass through solids and liquids.
- **S waves** are **transverse** waves:
  - S waves travel through the Earth at between 3 km/s and 5.5 km/s
  - S waves can only pass through solids.



Seismograph trace

D–C

Earth's insides

- P waves travel through the Earth:
  - they are **refracted** by the core
  - the paths taken by P waves mean that scientists can work out the size of the Earth's core.
- S waves are not detected on the opposite side of Earth to an earthquake:
  - they will not travel through liquid
  - this tells scientists that Earth's core is liquid.

B–A*

Tan or burn

- A tan is caused by the action of **ultraviolet** light on the skin.
- Cells in the skin produce **melanin**, a pigment that produces a tan.
- People with darker skin do not tan as easily because ultraviolet radiation is filtered out.
- Use a sun screen with a high SPF, or sun protection factor, to reduce risks.

  maximum length of time to spend in the sun = published normal burn time × SPF
- People are becoming more aware of the dangers of exposure to ultraviolet radiation, including the use of sun beds.

D–C

Ozone depletion

- At first scientists did not believe there was thinning of the ozone layer – they thought their instruments were faulty but other scientists confirmed the results and increased confidence in the findings.

D–C

- **Ozone** is found in the **stratosphere**.
- Ozone helps to filter out ultraviolet radiation.
- **CFC** gases from aerosols and fridges destroy ozone and reduce the thickness of the ozone layer.
  - This increases the potential danger to humans.
- The ozone layer is at its thinnest above the South Pole because ozone depleting chemicals work best in cold conditions.
- Scientists monitor the thickness of the ozone layer using satellites.
- There is international agreement to reduce CFC emissions.

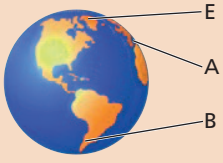
B–A*

Improve your grade

Earthquake waves

An Earthquake occurs with its epicentre at **E**. It is detected at two monitoring stations **A** and **B**.

Describe and explain the appearance of the seismograph traces at **A** and **B**.
AO1 / AO2 [4 marks]



P1 Summary

Heat and temperature

Energy is transferred when a substance changes temperature.

The amount of energy transferred depends on the mass, temperature change and specific heat capacity.

energy transferred = mass × specific heat capacity × temperature change

Energy is transferred from a hotter to a colder body.

Temperature is a measure of hotness on an arbitrary scale, measured in °C.

Energy is a measure of energy transfer on an absolute scale measured in J.

Energy is transferred when a substance changes state.

The amount of energy transferred depends on the mass and the specific latent heat.

energy transferred = mass × specific latent heat

Energy transfer

Air is a good insulator and reduces energy transfer by conduction

Conduction in a solid is by the transfer of kinetic energy.

Trapped air reduces energy transfer by convection.

Convection currents are caused by density changes.

Energy saving in the home can be achieved by:

- double glazing
- cavity wall insulation
- draught strip
- reflecting foil
- loft insulation
- curtains
- careful design.

Shiny surfaces reflect infrared radiation to reduce energy transfer.

Energy transformations can be represented by Sankey diagrams.

$$\text{efficiency} = \frac{\text{useful energy output (×100\%)}}{\text{total energy input}}$$

Waves transfer energy

Warm and hot objects emit infrared radiation.

Infrared radiation is used for cooking.

Microwaves can be used for cooking and for communication when transmitter and receiver are in line of sight.

Laser light is single colour and in phase.

Laser light, visible light and infrared are all used to send signals along optical fibres by total internal reflection.

All waves have amplitude, frequency and wavelength

wave speed = frequency × wavelength

Digital and analogue signals are used for communication.

Morse is a digital code.

Digital signals allow many signals to be transmitted at the same time.

Digital signals are clearer.

Radio waves, microwaves, infrared, visible light and ultraviolet are some of the waves in the electromagnetic spectrum.

The energy of the wave increases as the wavelength decreases.

All electromagnetic waves can be reflected, refracted and diffracted.

Radio waves are used for communication.

Longer wavelengths diffract around obstacles.

The stable Earth

Earthquake waves travel through the Earth.

Different waves help us find out about the inside of the Earth.

Exposure to ultraviolet radiation causes sun burn and skin cancer.

Sun screen and sun block reduces damage caused by ultraviolet radiation.

CFCs are causing the ozone layer to become thinner.